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ADVANCED COMPUTER TYPOGRAPHY

by

A. V. HERSHEY

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ABSTRACT

Horizontal justification adjusts the spacing between words to fit a line into the space between margins, whereas vertical justification adjusts the spacing between titles, paragraphs, and displays, to fit a page into the space between margins. In the original FORTRAN system horizontal justification was automatic, but vertical justification was manual. In the advanced HERA system both the horizontal justification and the vertical justification are automatic.

INTRODUCTION

A computer and a plotter can be used to prepare cartographic and typographic material with graphic arts quality. There are several systems¹⁻¹⁶ which operate through the computer. The CTI system was designed especially for mathematics by McQuillin^{5,6} in Cambridge. The TEX system was designed especially for mathematics by Knuth⁸ in Stanford. A FORTRAN system was designed by Hershey⁹⁻¹⁶ at the Naval Surface Weapons Center. This system is simpler than the other systems and it has a full range of cartographic and typographic capability. It has been replaced by the HERA system, which is a more advanced version. The HERA system is the subject of the present report.

The coast lines and the boundaries in conventional maps can be simulated by polygons. The edges of the characters on the faces of metal type or in the images of photographic plates can be simulated by polygons. The coordinates of the corners of the polygons are stored in the computer.

The pen of a mechanical plotter is moved by incremental motors from one point to another in a raster. The beam of a cathode-ray plotter is moved by electrostatic deflection from one pixel to another. A distinction must be made between the addressable raster with units equal to the smallest displacement of the pen or beam, and the resolvable raster with units equal to the smallest distance between distinct lines. The addressable raster usually is much finer than the resolvable raster. Then the jogs in the edges of lines are reduced to a level below visual acuity.

There are three methods for displaying characters. In the HERA method the characters are polygonized by eye to achieve optimum simulation. Each character is displayed by a series of strokes which are confined to the black area of the character. In the Mergenthaler⁷ method each type is scanned on parallel lines to determine the coordinates of the edges of the type. Each character is displayed in a series of scans by a beam which is off over the white area and on over the black area. In the TEX method the coordinates of the center of a pen are expressed by cubic parametric equations. Each character is displayed as a pattern of pixels whose centers are crossed by an elliptical pen.

There are three methods for the transmission of typographic control data to the computer. In many computer graphic systems¹⁻⁴ there is a large set of subroutines. A call to a particular subroutine resets one particular parameter for which the value is given in the call line. Textual data are transmitted as a Hollerith string. Although this method can reproduce an occasional formula, it is not adequate for the mass production of mathematical text. In the HERA system the typographic control data are transmitted to the computer in an input file. Textual data are located in textual records which tell the computer what to print, and functional data are located in functional records which tell the computer how to print. Each textual record is followed by any number of functional records. The linkage between textual data and functional data is through the column numbers in each textual record. A card deck or a computer terminal may be the source of records. With textual data and functional data in separate records, the textual data are easy to proofread. In the conventional method of input to the computer the textual data and the functional data are mixed in a single file. The transition from textual data to functional data is marked by an escape character. In the TEX system the escape character is a backslant. Parameter values

are labeled with a number sign. Parameters remain set through a group of characters which are bracketed by braces. Subscripts and superscripts are labeled with down arrows and up arrows. Mathematical material is bracketed with dollar signs. With the textual data and the functional data in a single file, the textual data are hard to find.

Adherence to convention is helpful to the reader. Footnotes, subscripts, and superscripts are printed in smaller type than the principal lines of type. Whenever a foreign word is substituted for an English word in the text the foreign word is printed in italics. Likewise a symbol which is substituted for a mathematical quantity is printed in italics. However, a symbol which stands for a set of mathematical quantities may be printed in bold-faced roman or in Old English. Standard abbreviations are printed in roman. The standard spacing between words in the text is one en. Smaller spacing is used between symbols in a mathematical expression. Letters which are grouped together to designate a mathematical quantity are set off from other symbols with space. Conjunctive and predicative signs are set off with space. In the HERA system the spacing between symbols in a mathematical expression is simplified to one half en. In the TEX system the computer parses the mathematical expression with the aid of tables and inserts an elaborate set of spaces.

Good composition is helpful to the reader. Composition is concerned with the placement of titles, paragraphs, and displays. A title may be compound with several lines. A paragraph may be flushed left or indented. A display may contain formulae, tables, or figures. The spaces between words in a paragraph are variable and are adjusted so as to justify the material horizontally. The space above a title is variable and the spaces above and below a display are variable. The spaces are adjusted so as to justify the material vertically. Other spaces are fixed. A page may not end with a title at the bottom or begin with a display at the top.

There are two methods for composition on the computer. In the HERA system the parts with fixed structure are patterns and the areas in between are space. Vertical justification is achieved in initial program steps which edit the input data and horizontal justification is achieved in the final program step which prints the page. In the TEX system the parts with fixed structure are boxes and the areas in between are glue. Vertical justification is achieved in a vertical mode and horizontal justification is achieved in a horizontal mode of a single program step which prints the page.

The only system with full capability in cartography and typography is the HERA system. It was designed especially for the printing of difficult material such as chemical structures, electronic diagrams, and mathematical equations. More than 120 copies of the original version of the system have been distributed under technology transfer. Versions have been prepared for a number of computers and plotters. The IBM version has been overhauled to replace assembler language with FORTRAN language. The IBM version makes calls to CalComp subroutines. Converters with multiple entry can be included with the main program. Then input can be prepared for any plotter with the same capability as the CalComp plotters. Thus output has been obtained from a DICOMED plotter in Minneapolis. In the original version of the system vertical justification was manual. In the advanced version of the system vertical justification is automatic. The advanced version has been used in the preparation of four reports¹⁷⁻²⁰ for the Naval Surface Weapons Center.

The principal programs in the system are FOLIO, which copies or synthesizes input data for folio, TEXT0, which copies or edits input data for text, CHRCTR, which copies or edits character data, and TPGPHC, which controls the preparation of output. The central subroutines in the system are CTGPHC, which prepares charts, TXGPHC, which prepares text, and FLGPHC, which prepares folio. Auxiliary subroutines are TKGPHC,

which counts the number of lines in each paragraph, and DKGPHC, which measures the height of each display. An auxiliary program PAGE computes extra spacing for vertical justification.

JOB CONTROL

It had been easy to set up the FORTRAN typographic system on a CDC 6600 computer, but it was difficult to do the same setup on the IBM 360 computer. It was necessary to use the FORTRAN IV (H) Extended compiler where the allowance for tables was adjustable to a maximum. The compiler would concatenate only members of a partitioned data set. It was necessary to add a job step in which the program deck was transferred to a temporary partitioned data set. Then the job control tables were too small. It was necessary to suppress the printing of compiled subroutines in order to make the computer accept as many as four job steps. In each job step the linkage editor assigns the same name to a system load module. If two succeeding job steps happen to be assigned to the same direct address device the job is cancelled. It is necessary to override the default name of each load module with a distinct name for each job step.

More efficient operation is possible when the source modules are replaced by load modules. However, the compiler would not compile more than one load module at a time. Conversion of source modules one by one to load modules required too much time because of slow turnaround.

The computer is prepared to copy programming for the IBM 360 computer from reel NPS432 and programming for the CDC 6600 computer from reel NPS440. In either case the tape contains two files. Subroutines ready to be copied into permanent files are provided in the first file, while a sample job setup is provided in the second file. All data and programming are in EBCDIC format at 800 BPI on 9-track tape.

CHARACTER DATA

Each character in the character repertory has a character number. Polygonization of each character is expressed by coordinates relative to the centroid of the character. The character number is the address of the character in an index array AI. Each datum in the index array is the address of the character in a datum array AD. Each byte of the datum array is a coordinate of the polygonization. Packing and unpacking of data in the arrays requires bit manipulation.

BIT MANIPULATION

The bit manipulation in the original version for the IBM computers was done in assembler language. It is possible to write all subroutines in FORTRAN. On CDC computers FORTRAN Extended makes possible the manipulation of bits through Boolean algebra and the SHIFT function. On IBM computers FORTRAN IV makes possible the manipulation of bits through division by powers of 2. Any configuration of bits in a 32-bit word is recognized as an integer if the word is designated implicitly as an integer or is defined by a type declaration. Floating point numbers may be given an integer alias by an equivalence statement.

If the leftmost bit is zero, the number is positive. Division by a power of 2 shifts bits to the right and discards any overflow. Conversely, multiplication by a power of 2 shifts bits to the left.

If the leftmost bit is one, the number is negative. The bit configuration is that complement which is obtained when a positive number is subtracted from zero. Cancellation of bits in the negative number increases its absolute value. The sign bit therefore must be eliminated before division by a power of 2. The bits of the negative number are the same as when its absolute value is subtracted from $2^{**}31$. Although $2^{**}31$ is larger than the largest number in the computer, its addition can be accomplished by the addition of $2^{**}30$ twice. Thus if N is the negative number, then the expression

$$1073741824 + N + 1073741824$$

has the same bits as the number N but without the sign bit. The success of the expression depends upon the hierarchy of operations. After division by a power of 2 the sign bit must be restored to its new position in the number with shifted bits.

The equivalence

$$Z80000000 = - 1073741824 - 1073741824$$

makes it possible to construct bit configurations which have a one in the leftmost bit position.

A common application of bit manipulation is the conversion of an A1 format with a character in the leftmost byte into the integer equivalent of the character. The integer is given by the expression

$$\frac{N}{16777216}$$

when the integer is positive and is given by the expression

$$\frac{(1073741824 + N + 1073741824)}{16777216} + 128$$

when the integer is negative. In these expressions N is the word with A1 format.

Reconversion of an integer into an A1 format can be based upon the equivalence

$$Z00404040 = + 4210752$$

when the integer is less than 128. Reconversion of an integer into an A1 format can be based upon the equivalence

$$Z80404040 = - 2143272896$$

when the integer is equal to or greater than 128. Thus the integer is shifted to the leftmost byte and the word is padded out with blanks.

UPDATE

The editing of input data and the modification of subroutines can be achieved with the aid of an update utility.

The Control Data Corporation has an update utility with an especially simple control deck. Command records begin with an asterisk in the first column. Each command record is followed by any number of records to be inserted. The only limitation is that records to be inserted must not have an asterisk in the first column. The input file may have any number of records with an asterisk in the first column as long as they need not be replaced.

The Computer Center has a utility program called UPDATE. This utility program drops records from the output file. The IBM Corporation has a utility program called IEBUPDTE. This utility program is awkward to use for insertions. Both utility programs require that the last eight columns of each record be devoted to sequence numbers.

A new program UPDATE has been written in FORTRAN. It keeps a count of sequence numbers and the last eight columns of the records are left intact. The program can be used in a job step where a source file is revised and transferred to a temporary file. It can be followed by a compile job step in which the temporary file is translated into a load module. The control file contains four command records.

*ASSIGN (NI,NO)

tells the computer what FORTRAN unit numbers have been assigned to the input file and the output file.

*INSERT K

is followed by any number of records which are to be inserted after the record with sequence number K.

*DELETE K

or

*DELETE (I,J)

is followed by any number of records which are to be inserted after deletion of one record with sequence number K or after the deletion of a set of records which begin with the sequence number I and end with the sequence number J.

*CONTINUE

tells the computer to copy the remainder of the input file to the remainder of the output file.

CONTROL DATA

The textual data are read into an array KD and the functional data are read into an array KC. Interpretation of the data in these arrays defines each character in a line of print. The number of the character, the X-coordinate of its centroid, and the Y-coordinate of its centroid are stored in three addresses in an array MC. Under nonjustification the contents of array MC are transferred to an array MD. Under automatic justification each word with a blank is transferred from the array MC to the array MD until the next word would overhang the right margin. If the amount of overhang is greater than half the width of the word with a blank, then the word is not transferred and the blanks in array MD are stretched to fit the line into the space between margins. If the amount of overhang is less than half the width of the word with a blank, and if the blanks would not be shrunk to less than half, then the word with a blank is transferred and the blanks in MD are shrunk to fit the line into the space between margins.

On the CDC computer the card reader and the output printer were used in the preparation of control data. A copy of the manuscript was handed to a staff of keypunch operators who punched a deck of textual records. The textual deck was listed by a program which counted the number of records and printed the number opposite each printed record. Below each textual record a scale with tick marks was printed to indicate column numbers. Below each scale a space was provided where functional records could be added in red. Then the listing was handed to the keypunch operators who punched a deck of functional records. Likewise the textual data for displays were

recorded on one set of forms and keypunched, while the functional data for the displays were recorded on another set of forms and keypunched. Originally the four decks were collated and assembled by hand, but this came to be too much of a burden. Then the decks were stored intact in the computer and collated when necessary. Errors in the control decks created problems of synchronization.

In the current installation there is no staff of keypunch operators, but there are many display terminals under CMS. The textual records can be keyed into the computer and the functional records can be added in place. A record number can be displayed next to each record, and column numbers can be read from a scale with tick marks. The records are edited easily with the aid of subcommands under XEDIT.

Textual records for titles and paragraphs all are blank in column 80. Paragraphs are distinguished from titles by the presence of AJ in the functional data which sets the system into the automatic justification mode, and by the presence of NJ in the functional data which sets the system into the nonjustification mode. The positions of lines of display are marked in the text file by cue records which are blank everywhere except in column 80. The cue record for a row of asterisks is blank except for an asterisk in column 80. The cue record for an unnumbered line of display is blank except for a solidus in column 80. The cue record for a numbered line of display is blank except for the right-justified display number.

The serial numbers of titles and displays, and the number of lines in each paragraph are listed in a file TK. The determination of the number of lines for each paragraph in a file TX is made with the aid of the subroutine TKGPHC. A count of the number of times that array MD is unloaded gives the number of lines. The count starts with the appearance of AJ and ends with the appearance of NJ. The preparation of the file TK is made in conjunction with the checkout of paragraphs, but without actually printing the paragraphs.

The distance from the top of a display to the first line, the distance from the first line to the last line, and the distance from the last line to the bottom of the display are given in a file DK. The determination of distances for each display in a file DX is made with the aid of the subroutine DKGPHC. The distances are derived from a search for the upper bound of the uppermost character in the first line, from the distances between the centroids of the lines, and from a search for the lower bound of the lowermost character in the last line. The preparation of the file DK is made in conjunction with the checkout of displays, but without actually printing the displays.

Whenever there is to be extra spacing in the text the amount of spacing and the serial number of the previous line are stored in a file KK. The determination of the amount of extra spacing is made with the aid of a program PAGE. Control records from files TK and DK are read into a ladder where they can be compared and interpreted. Whenever there is to be extra space a record is written in a temporary file. The record is coded to distinguish between fixed space and variable space. While control records are being processed, the height of each line is accumulated in a height parameter. When the height with a new line would exceed the distance from the top margin to the bottom margin, the disparity between the last line and the bottom is distributed over the variable spacing, and the adjusted spacings are transferred to the file KK. Thus the printed material is justified vertically.

The several titles and subtitles in a group of titles are set off with extra spacings. Between a title and a following paragraph the spacing is fixed, but between a paragraph and a following title the spacing is variable. If all of the titles and subtitles in a group of titles with an additional line of paragraph cannot be fitted within the bottom of the page, then the whole group of titles is moved to the next page.

Every display is set off with extra spacings which are variable. If a display can be fitted within the bottom of the page but not with a following line of paragraph, then the line of paragraph is moved to the next page. If a line of paragraph and a following display cannot be fitted within the bottom of the page, then the line of paragraph and the display are moved together to the next page.

The program PAGE is fully automatic, but there is provision for intervention in the event of an irresolvable conflict. One such conflict would be a page of paragraphs which ends with a display at the bottom. There would be no variable spacing to be adjusted so as to move the last line before the display over to the next page. Special spacing could be introduced higher in the text or between paragraphs.

In the final printout a special program TEXT0 assembles data from files TX, DX, and KK into input for a standard program TPGPHC. The computer keeps a record of the character in column 80 of the text file during shifts between titles, paragraphs, and displays. When the character switches from one blank to another blank, extra spacing is inserted with the code

HV,0000,YYYY,

where YYYY is the extra spacing. When the character switches from blank to nonblank, the extra spacing is inserted with the code

HV,0000,YYYY,XHVT,

When the character switches from nonblank to blank, the extra spacing is inserted with the code

HV,0000,YYYY,XNVP,

Thus all displays start automatically with half spacing between words and in tertiary variant, while all paragraphs start automatically with normal spacing between words and in primary variant.

Printing by program TPGPHC continues as long as no line would overflow the bottom of the page. The possibility of overflow triggers an automatic frame advance and printing continues at the top of the next page.

CHECKOUT

The text file is checked out in a run which prints paragraphs and cue records. Inasmuch as each line has the same height the lines fit within the margins. The display file is checked out in a run which prints each display centered in a separate frame. Advance from frame to frame is triggered by a blank record with extreme displacement.

TRANSLATION

The original version of the HERA system has been translated from FORTRAN into BASIC, and is available for use on home computers. Characters of indexical size have been replaced by characters of normal size at two-thirds scale. This simplification is made possible by the fineness of the addressable rasters in current plotters. In order to fit data and programs into 32K memory, the number of characters has been limited to 255. However, it is possible to swap character sets during printing. Control data for BASIC programs are in ASCII characters. Inasmuch as the ASCII character repertory is much larger than the FORTRAN character repertory, it has been possible to cut the number of variants from four to two. Compact storage of data is possible because any

integer less than 256 can be stored in each eight-bit byte of a string array.

Data bases for the system have been transported by telephone from the IBM3033 computer to the HP85 computer. Required for the transport are a Princess telephone, a D-CAT modem, and an RS-232C interface. The modem is set to originate half-duplex at 300 baud. The interface is set to interpret ten-bit signals in which the first bit is a start bit, the next seven bits are character bits, and the last two bits are stop bits. In the transport of map data the latitude is expressed as minutes north of the South Pole and the longitude is expressed as minutes east of the 180th meridian. The coordinates of each point are transported as six-digit integers separated by a comma, then each coordinate to base 256 is stored as a pair of ASCII characters. In the transport of character data the coordinates are offset by 64. Three techniques of transport are conceivable. The most efficient would be the substitution of a single ASCII character for each seven-bit number, but the IBM computer will send over only bit configurations for standard alphameric symbols. The next efficient would be the use of two characters to express the hexadecimal representation, and this is the technique actually used. The least efficient would be the use of three characters and a comma to express the decimal representation.

Each computer must wait while the other computer does its thing. When the IBM computer has been informed that it is connected to a terminal, then it waits for a reply from the HP computer. The wait instruction is used to make the HP computer wait until the transmission from the IBM computer has been completed. Each transmission from the IBM computer is terminated with a CTRLQ or an ASCII #17 character, while each transmission from the HP computer is terminated with a CTRLS or an ASCII #19 character.

DISCUSSION

The ultimate demonstration of the HERA system is the four reports from the Naval Surface Weapons Center¹⁷⁻²⁰. These reports were justified vertically without intervention so that they would illustrate the performance of the system. They could have been improved in a couple of places by intervention.

In the current installation the IBM3033 computer has an MSS or Mass Storage System, an MVS or Multiple Virtual System, and a CMS or Conversational Monitor System. The CMS cannot communicate with the MSS or with the Versatec, but it can submit data and programs to the MVS. Therefore the CMS is used in the present system as a replacement for the keypunch and the card reader in the old system. In the present version of the HERA system there are three job setups with five program steps each and files from each setup must be stored on Disk 01. Future improvements could include a compression of the system to a single setup.

CONCLUSION

It has been possible to set up the full HERA system on the IBM computer, where entire reports can be printed with multiple pagination. It has been possible to compress the HERA system into a limited version for the HP computer, where single pages can be printed one at a time.

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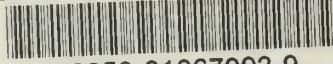
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